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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Electric Motor Assembly

We, FRANKLIN ELECTRIC CO., INC., a corporation organized under the laws of the State of Indiana, United States of America, of Bluffton, Indiana, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the interconnection of a number of individual electric motor units, and to an assembly of such electric motor units.

It has become common practice to use submersible motors in wells for pumping and for performing other operations in the wells. As the practice has increased, the demand for larger power motors has likewise increased.

Of course, to increase the power of motors requires an increase in the size of motors. However, motors for use in drilled wells and the like must be limited to a relatively small diameter, since they have to be inserted in the well casing. Thus, to provide more power, well motors have been lengthened as far as practical, but shaft vibration and other factors have imposed a limit on the length of rotor for motors that can be used in casings of usual diameters.

The present invention provides an electric motor interconnecting unit for effecting electrical connection between and mechanically connecting together in axial alignment a pair of electric motor units, each having similarly positioned axially facing electric connector elements, and comprising a generally tubular member having means at its ends for attachment to the respective motor units, means located within said tubular member and adapted to connect the motor shafts of the motor units for operation in unison, and interconnected electrical connector elements at the ends of said tubular member, said electrical connector elements of said interconnecting unit having

fixed locations on said tubular member and adapted to mate with the electrical connector elements of the motor units and being automatically movable into operative electrical engagement therewith upon movement of said interconnecting unit into attached relation with said motor units, and sealing means forming a liquid tight seal around said electrical connector elements when said interconnecting unit is attached to the motor units.

The present invention also provides a submersible electric motor assembly comprising at least two motor units arranged in axially aligned end-to-end relation, each of said motor units having a rotor mounted on a rotor shaft projecting axially of the motor unit and a stator around said rotor and including a field winding, each motor unit further including at its end which is adjacent the other motor unit a plurality of electrical connector elements which are electrically connected to the field winding of the associated motor unit and have fixed locations relative to the stator, and an interconnecting unit positioned between said adjacent ends of said motor units and releasably secured to said stators of said motor units for holding said motor units in said end-to-end assembled relation and for connecting said rotor shafts together for operation in unison, said interconnecting unit further including interconnected electrical connector elements at both axial ends thereof, said connector elements of said interconnecting unit having fixed locations on said interconnecting unit and being located to automatically engage said electrical connector elements of said motor units upon movement of said interconnecting unit into secured relation with said motor units, said electrical connector elements of said interconnecting unit connecting the field windings of said motor units together when said interconnecting unit is secured to said motor units, and sealing means between said motor units and said interconnecting unit forming liquid

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tight seals around said connector elements when said motor units are in secured relation with said interconnecting unit.

The motor structure of the present invention provides increased power for use in wells and the like. It includes a plurality of motor units and may have a single coolant and lubricant system for the assembly, a single thrust bearing device arranged to bear the thrust developed by all of the units, and can be operated with only a single set of power leads.

The objects and advantages of the invention will be apparent from the following description taken in conjunction with the accompanying drawings wherein:

Figure 1 is a longitudinal sectional view, on a reduced scale, of a submersible motor assembly embodying the present invention, Figure 1 being taken substantially along line 1—1 in Figure 2;

Figure 2 is a top end view of the assembly shown in Figure 1;

Figure 3 is an end view of a connector member used in the assembly shown in Figure 1;

Figure 4 is a sectional view taken along line 4—4 in Figure 3;

Figure 5 is a sectional view taken along line 5—5 in Figure 1;

Figure 6 is a sectional view taken along line 6—6 in Figure 1; and

Figure 7 is a diagrammatic view showing one way of arranging the field windings in the assembly shown in Figure 1.

Figure 1 shows a preferred form of motor assembly embodying the features of the present invention. Thus, the assembly comprises a pair of motor units, indicated generally at 11 and 12, arranged in axial alignment and rigidly connected together by an interconnecting unit indicated generally at 13. The upper end of the assembly is covered by an end termination unit 14 from which projects a shaft portion 16, connectable to a driven device, such as a pump. As will be seen hereafter, the shaft 16 transmits the power of both motor units 11 and 12 to such driven device. The lower end of the assembly is closed by a lower termination unit 17.

The motor units 11 and 12 are substantially alike, being elongated and cylindrical and comprising the usual stator and rotor elements. Thus, each of the motor units 11 and 12 comprises a stator including the usual stack of laminations 18 and field windings 19 arranged in a conventional manner. Each unit has its stator enclosed by a casing comprising a cylindrical sleeve 21 on the outside of the stator and a thin cylindrical liner 22 on the inside of the stator, thus defining an annular space therebetween. At their opposite ends, the sleeve 21 and liner 22 are secured, as by welding, to annular end rings 23 and 24, and seal the stator in the annular space.

The present units 11 and 12 are three phase

units, and thus each of their stators has three field windings. As diagrammatically shown in Figure 7, the unit 11 has field windings 36, 37, and 38, and the unit 12 has field windings 39, 41 and 42. The windings 39, 41 and 42 are interconnected, in the usual manner, as shown in Figure 7, to form a wye connection at the lower end of the motor unit 12. The windings 36, 37 and 38 are not so interconnected.

Each of the motor units 11 and 12 also has a rotor 26 and the rotors 26 are respectively mounted on rotor shafts 27 and 28. The rotors 26 are of the squirrel cage type and their shafts project axially from the units, as shown.

The present assembly is equipped with a coolant system and to this end, the motor units 11 and 12 have passages for carrying coolant fluid through the unit. Thus, the shaft 27 has an axial bore 29 that connects to a radial bore 31 at the upper end of the shaft 27 for carrying coolant in one direction through the motor unit 11. Coolant passes in the opposite direction through the motor unit 11 through an axial space, indicated at 32, between the liner 22 and the rotor 26. Similarly, in the unit 12 the rotor shaft 28 is provided with an axial bore 33 for carrying coolant fluid through the unit 12 in one direction, and space 34, between its rotor 26 and the liner 22 of the unit 12, carries such coolant in the opposite direction through the unit 12.

The interconnecting unit 13, connecting the motor units 11 and 12 in end-to-end axial alignment, not only rigidly interconnects the motor units but also makes the electrical connections necessary to connect the windings of the units in series interconnects the fluid passages in the two motor units together and interconnects the rotor shafts 27 and 28 together for rotation in unison. Thus, the interconnecting unit 13 comprises a tubular member 43 which is, in effect, a dual end bell member shown in detail in Figures 3 and 4. The tubular member 43 rigidly interconnects the adjacent ends of the stator casings of motor units 11 and 12. For this purpose, the member 43 is provided with a pair of axially spaced flanges 46 and 47 which abut against the end ring 24 of motor unit 11 and end ring 23 of motor unit 12. The flanges are secured to the end rings as by screws 48. Four longitudinal ribs 45 join the flanges 46 and 47 for strengthening the member 43.

The member 43 provides bearings for the adjacent ends of the shafts 27 and 28. In this instance, member 43 has bearing support portions 49 and 51 that project axially into the motor units 11 and 12, respectively, and are provided with radial bearings 52 and 53. The radial bearing 52 supports the lower end of shaft 27, as shown in Figure 11, while the bearing 53 supports the upper end of the shaft 28. The bearings 52 and 53 are exposed to the fluid in the assembly and have helical

grooves 50 (see Figure 4) for passing the fluid through the bearings 52 and 53. Hence, these bearings are lubricated by the fluid.

5 The member 43 also interconnects fluid passages in the motor units. To this end, the member 43 is provided with a pair of longitudinally extending slots 54 that extend to openings 55 through the portions 49 and 51 and thus provide flow communication from the
10 space 32 in the upper unit to the space 34 in the lower unit. Coolant fluid may thus pass from the space 32 in unit 11 over the outside of the portion 49, through the openings 55, downwardly through the slots 54, out through
15 the openings 55 in the portion 51 and over the portion 51 into the space 34 at the upper end of the motor unit 12. To prevent leakage of liquid at the ends of the member 43, the latter is provided with sealing means comprising
20 a pair of "O" rings 56 mounted in circumferential grooves located adjacent the flanges 46 and 47. The "O" rings 56 engage the end ring 24 of the upper unit and the end ring 23 of the lower unit, respectively.

25 The interconnecting unit 13 also includes means for interconnecting the adjacent ends of the shafts 27 and 28 for segregating the fluid passage through the center of the shafts from the fluid passage provided, in part, by the slots
30 54. To this end, the adjacent ends of the shafts 27 and 28 are splined, as shown at 72, in Figure 1, and a sleeve 44 having internal splines cooperating with the splines on the shafts 27 and 28 is telescoped over the ends
35 of the shafts. To transfer thrust from the shaft 27 of the upper unit to the shaft 28 of the lower unit, a washer 75 is interposed between the ends of the shafts within the sleeve 44. At its opposite ends, the sleeve 44 is provided
40 with internal circumferential grooves containing "O" rings 73, which seat on the shafts beyond the splines. Thus, the sleeve 44 provides a driving connection between the shafts 27 and 28. The sleeve 44 also bridges the
45 space between the ends of the shafts and segregates the passage formed by the bores 29 and 33 in the shafts from the fluid passage outside the shafts, which includes the slots 54. In this connection, it should be noted that the sleeve
50 44 and the member 43 are in circumferentially spaced relation, the space between the sleeve 44 and the member 43, being included with the slots 54 as the fluid passage outside the shafts.

55 In the present assembly, the field windings 36, 37 and 38 of the upper motor unit 11 are connected in series with the field windings 39, 41 and 42, respectively, and only a single set of power leads is required for the assembly.
60 To make these connections, the member 43 is provided with an electrical connector device 59 that cooperates with mating connector elements in the units 11 and 12 to form the connections when the member 43 is secured to
65 the ends of the motor units 11 and 12. As

shown in Figure 1, the end ring 24 of the motor unit 11 is provided with a hole and mounted therein is a connector element 57 having three prongs respectively connected to
70 the three field windings of the unit, one prong being shown at 60. Likewise, the lower motor unit 12 has a similar electrical connector element 58 mounted in a hole in its end ring 23.

75 The connector device 59 is an elongated structure and extends through the member 43. Each end of the device 59 has three tubular sockets 61 receiving the prongs 60 of the connector elements 57 or 58. As indicated in
80 Figure 4, the sockets 61 are formed in the two ends of conductors 62. The conductors 62 are embedded in a pair of bushings 63 and 64 of resilient insulating material, the inner ends of which are enclosed by a tube 65 of
85 insulating material and located in a bore 66 formed in one of the ribs 45 which joins the flanges 46 and 47.

90 When the connector device 59 is engaged with the connector elements 57 and 58 and the member 43 is secured to the end rings 24 and 23, the bushings 63 and 64 are compressed and seal against the end rings within
95 the holes therein and against the elements 57 and 58. Sealing is also provided by a circumferential flange 68, formed on each of the bushings 63 and 64. The flanges 68 are confined by metal rings or ferrules 69 which
100 seat in circular grooves or recesses 71 when the parts are assembled. The metal ring 69 prevents the flange 68 from being spread out and pinched by the adjacent metal parts when the screws 48 are pulled tight. The ring 69
105 also assists in preventing misalignment of the facing metal parts due to bulging of the resilient flange 68. Thus, it can be seen that the windings of the motor units are automatically connected together in series and sealed by the
110 connector device 59 when the tubular member 43 has been secured to its associated motor units.

115 At the upper end of the assembly, the upper end termination unit 14 is secured to the end ring 23 of the upper motor unit 11 as by a plurality of circumferentially arranged screws 74. In the present instance, the screws 74 also
120 extend upwardly from the upper end termination unit 14 for a connection to a device to be driven by the motor assembly, such as a pump. The unit 14 includes an inwardly extending tubular portion 76 concentric with the
125 shaft 27 and carrying a bearing 77 that supports the shaft portion 16, mentioned above, which is a shaft extension telescopically forced on the upper end of the shaft 27. The upper
130 end of the shaft portion 16 is splined, as shown at 78 in Figures 1 and 2, for cooperation with a mating spline shaft in the pump. A seal 79 is mounted in the unit 14 for cooperation with the shaft portion 16.

The upper end termination unit 14 also has

means for connecting the assembly to a power line. In this instance, the end ring 23 of the upper motor unit has a hole in which a connector element 81 is mounted. A mating connector element 82 has three terminals connected to three motor supply leads 83. When the upper termination unit 14 is mounted on the upper motor unit 11 and secured thereto, the connector elements 81 and 82 are engaged and both motor units are thus connected for operation. The connector elements 81 and 82 cooperate with each other in substantially the same manner as the connector element 57 and the connector device 59.

Other important features of the present invention are embodied in the lower termination unit 17. This unit comprises a ring portion 84 threaded into a housing portion 86 and sealed by an "O" ring 87 (see Figure 1) which is confined by the ring portion 84, the housing portion 86 and the end ring 24 of the lower motor unit. The ring portion is secured to the end ring 24, by screws 88, and has a bearing support portion 89 on its upper end, projecting into the end of the lower motor unit. The portion 89 supports a radial bearing 91, which, in turn, carries the lower end of the shaft 28 of the lower unit 12. Passages 92 through the portion 89 connect the fluid passage provided by the space 34 with the interior of the lower termination unit 17. Fluid also flows through the bearing 91 and lubricates the same.

The housing portion 86 of the lower termination unit 17 is in the form of an elongated tubular structure closed at its lower end by a resilient diaphragm 93, which constitutes a receptacle for enclosing elements of the assembly and for collecting coolant fluid after it has been circulated through the assembly. In the housing portion 86 are located means for circulating the coolant fluid through the assembly, and thrust bearing means supporting the thrust forces in the assembly. The portion 86 also contains means coacting with the thrust bearing means to adjust the axial position of the shafts in the assembly.

The diaphragm 93 is located in the lower end of the portion 86 and is held in position by a sheet metal disk 96 forced into the lower end of the portion 86. The disk 96 is separated from the diaphragm 93 by a coil spring 97. Coolant fluid will fill the space, indicated at 94, above the diaphragm 93 and will contact the inner face of the diaphragm 93. Liquid on the outside of the assembly will contact the outer face of the diaphragm 93 by passing through an opening 98 in the center of the disk 96. Thus, the diaphragm 93 functions as a pressure equalizer for the coolant system in the assembly.

Intermediate its ends, the housing portion 86 of the lower termination unit 17 is provided with transversely extending support structure 99 on which is carried a thrust bearing 101 for the assembly (see Figures 1 and 5). The

thrust bearing 101 comprises a plurality of bearing segments 102 rockably mounted on a stationary disk 103. The disk 103 is centrally supported by an axially extending screw 104 threaded in the support 99 and held against rotation by a lug 100 on the portion 86 and projecting into a notch 100a, in the disk 103. The segments 102 bear against a bearing ring 106 on a disk 107 secured to the lower end of the shaft 28 by a key 108. Thus, it can be seen that the entire thrust load on the shafts 27 and 28 will be carried by the thrust bearing 101.

For circulating the coolant fluid through the assembly, the upper surface of the disk 107, which rotates with the shaft 28, is provided with impeller vanes 109 and a sheet metal shroud 111, forming a pump. The inlet to the shroud 111 is located adjacent the passages 92 and its outlet is in the space 94 at the thrust bearing. Thus, coolant will be circulated into the space 94, up through the bores 33 and 29 in the shafts, out through the radial bores 31, down through the space 32 between the rotor 26 of the upper motor unit and its liner 22, into the top openings 55 as well as into the top of the groove 50 in the bearing 52, down through the groove 50, the passage formed by the slots 54 in the member 43 and the space between the member 43 and sleeve 44, through the lower openings 55 and through the groove 50 in bearing 53, down through the space 34 between the rotor 26 and the liner 22 of the lower motor unit 12, and through the passages 92 and bearing 91 to the vanes on the disk 107.

The fluid circulating through the assembly will, of course, pick up much heat as it circulates through the two motor units. To dissipate this heat, the lower termination unit has a relatively large surface area inside the unit in contact with the fluid being circulated, the area extending from the bottom of the ring portion 84 down to the diaphragm 93. The unit also has a relatively large outer surface in contact with ambient fluid. Hence, the lower termination unit acts as a heat exchanger for the assembly's coolant system.

To fill the cooling system with fluid, the portion 86 is provided with an opening 116 having a removable threaded plug 117.

As was mentioned heretofore, the lower termination unit contains means for adjusting the position of the shafts in the assembly. To adjust the axial position in the assembly of the shafts 27 and 28, the screw 104 is rigidly secured to a toothed worm wheel 112 cooperating with a worm 113. Rotation of the worm 113 rotates the wheel 112 and the screw 104 and thus raises or lowers the thrust disk 103. This, in turn, shifts the shafts 27 and 28 axially. The worm 113 is rotatably mounted in the wall of the housing portion 86 and one end of the worm 113 is accessible from the exterior of the housing portion, as shown in Figure 6,

so that it may be readily adjusted. A screw 114 is mounted in the worm wheel 112 and engages ribs 115 extending from the support structure 99 to prevent undue rotation of the screw 104.

5 The end-to-end arrangement of the units permits a manufacturer to increase the power of an assembly merely adding a motor unit and connector unit to the assembly intermediate the end termination units. It will, of course, be recognized by those skilled in the art that such an addition requires a corresponding voltage increase in the power leads to the assembly. Hence, an assembly of relatively large power, for use in wells and the like, can easily be provided by a manufacturer. Moreover, the structure is such that assemblies of different power can be provided, using only one size of motor units and one size interconnecting units.

WHAT WE CLAIM IS:—

1. An electric motor interconnecting unit for effecting electrical connection between and mechanically connecting together in axial alignment a pair of electric motor units, each having similarly positioned axially facing electric connector elements, and comprising a generally tubular member having means at its ends for attachment to the respective motor units, means located within said tubular member and adapted to connect the motor shafts of the motor units for operation in unison, and interconnected electrical connector elements at the ends of said tubular member, said electrical connector elements of said interconnecting unit having fixed locations on said tubular member and adapted to mate with the electrical connector elements of the motor units and being automatically movable into operative electrical engagement therewith upon movement of said interconnecting unit into attached relation with said motor units, and sealing means forming a liquid tight seal around said electrical connector elements when said interconnecting unit is attached to the motor units.

2. An interconnecting unit as in claim 1, wherein said interconnected electrical connector elements of said interconnecting unit comprise at least one electric conductor which extends longitudinally of said tubular member and has coupling portions at its opposite ends for sliding engagement with mating electrical connectors of said motor units.

3. An interconnecting unit as in claim 2, wherein said tubular member has at least one longitudinally extending bore formed therethrough, and said electric conductor is mounted in said bore.

4. An interconnecting unit as in Claim 2, wherein said electrical connector elements of said interconnecting unit comprise an assembly of electrodes embedded in an elongated resilient body, said body being made of electrical insulating material and insulating said electrodes from said tubular member, said body

further forming a liquid tight seal around said electrodes when said interconnecting unit is attached to the motor units.

5. A submersible electric motor assembly comprising at least two motor units arranged in axially aligned end-to-end relation, each of said motor units having a rotor mounted on a rotor shaft projecting axially of the motor unit and a stator around said rotor and including a field winding, each motor unit further including at its end which is adjacent the other motor unit a plurality of electrical connector elements which are electrically connected to the field winding of the associated motor unit and have fixed locations relative to the stator, and an interconnecting unit positioned between said adjacent ends of said motor units and releasably secured to said stators of said motor units for holding said motor units in said end-to-end assembled relation and for connecting said rotor shafts together for operation in unison, said interconnecting unit further including interconnected electrical connector elements at both axial ends thereof, said connector elements of said interconnecting unit having fixed locations on said interconnecting unit and being located to automatically engage said electrical connector elements of said motor units upon movement of said interconnecting unit into secured relation with said motor units, said electrical connector elements of said interconnecting unit connecting the field windings of said motor units together when said interconnecting unit is secured to said motor units, and sealing means between said motor units and said interconnecting unit forming liquid tight seals around said connector elements when said motor units are in secured relation with said interconnecting unit.

6. An assembly as in Claim 5, wherein each of said motor units further includes a sealed axially extending casing containing said stator, and said interconnecting unit cooperates with said casings of said motor units to form an elongated chamber to receive a cooling fluid.

7. An assembly as in Claim 6, wherein said motor units have fluid passages formed therein for a cooling fluid, and said interconnecting unit also has fluid passages formed therethrough connecting said fluid passages of said motor units together to provide a single cooling system for the assembly.

8. An assembly as in Claim 7, wherein a portion of said fluid passages comprises axial bores in said rotor shafts for carrying the coolant in one direction through said assembly, said bores being interconnected by said interconnecting unit.

9. An assembly as in Claim 5, wherein said interconnecting unit includes a coupling sleeve for interconnecting said rotor shafts of said motor units for said operation in unison, each of said rotor shafts having an axial bore formed therethrough to provide a fluid passageway for a cooling fluid, said coupling

5 sleeve further interconnecting said axial bores, said interconnecting unit further including a tubular member forming an outer wall, and said sleeve being located in concentric spaced relation from said outer wall to provide a pas-
sageway for fluid flow therebetween.

10 10. An assembly as in Claim 9, and further including means for circulating a fluid through said passages.

15 11. An assembly as in anyone of Claims 5—10, wherein the electrical connector elements of said interconnecting unit extend longitudinally of said interconnecting unit, the opposite ends of said electrical connector elements of said interconnecting unit being located to automatically engage said electrical connector elements of said motor units upon movement of said interconnecting unit into secured relation with said motor units.

20 12. An assembly as in any of Claims 5—11, and further including an upper end termination unit mounted on the upper end of the uppermost of said motor units for substantially sealing the upper end of the assembly, said uppermost of said motor units having an extension of its rotor shaft projecting through said upper end termination unit for engagement with apparatus to be driven, and a lower end termination unit mounted on the lower end
25 of the lowermost of said motor units substantially sealing the lower end of said assembly, said lower end termination unit including a thrust bearing, fluid pressure equalization means, and a coolant heat exchanger.

30 13. An assembly as in anyone of Claims 5—11, including an upper end termination unit releasably secured to the upper end of the uppermost of said motor units substantially sealing the upper end of the assembly, said
35 uppermost of said motor units having an ex-

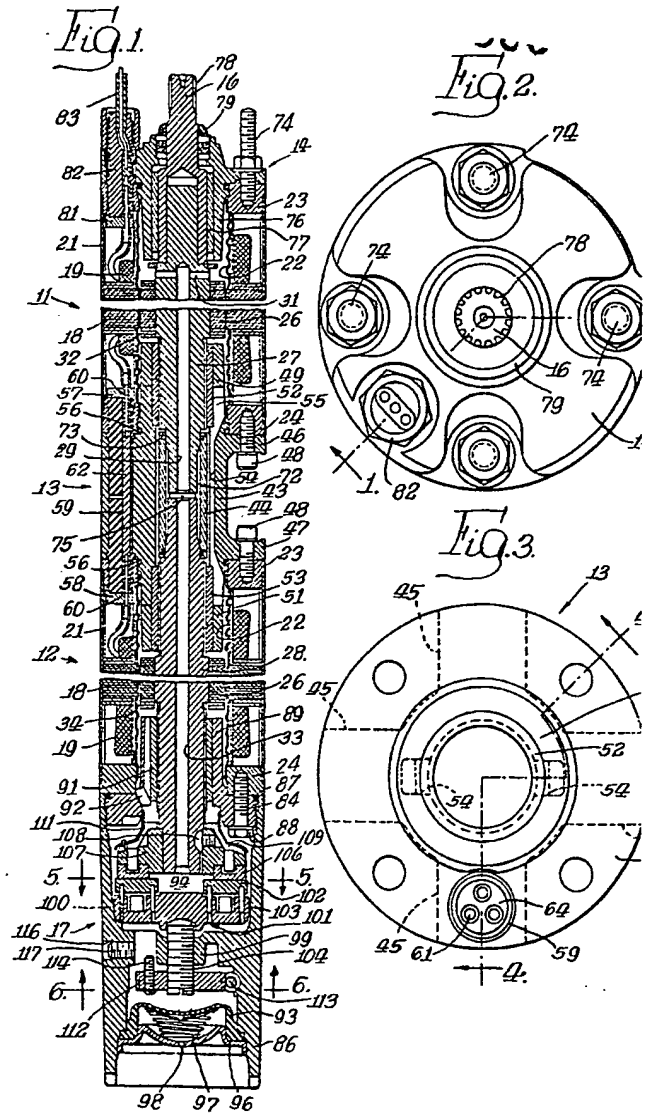
tension of its rotor shaft projecting through said upper end termination unit for engagement with apparatus to be driven, said upper end termination unit having electrical connector elements mounted in fixed locations thereon and being similar to said electrical connector elements of said interconnecting unit, and said uppermost motor unit having electrical connector elements mounted in fixed locations thereon and located to automatically engage said connector elements of said upper end termination units upon movement of said upper end termination unit into secured relation with said uppermost motor unit, said electrical connector elements at the upper end of said uppermost motor unit being connected to the field windings of said uppermost motor unit, and said electrical connector elements of said upper end termination unit being connectable to a source of electric power.

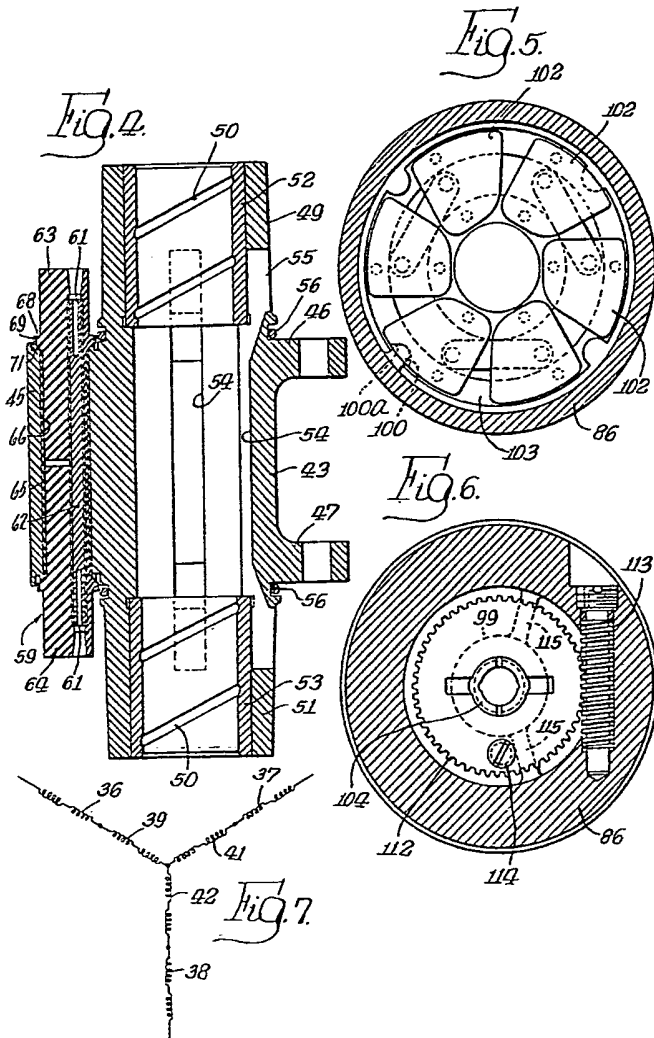
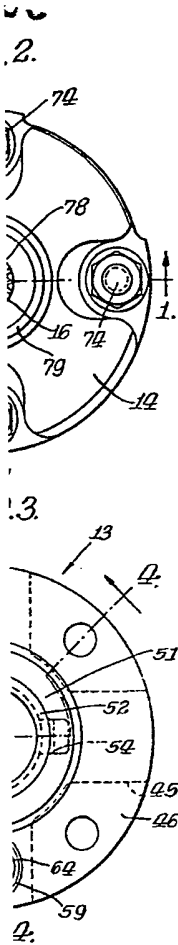
60 14. An assembly as in anyone of Claims 5—13, wherein said electrical connector elements of said motor units and said interconnecting unit are in the form of plugs and sockets.

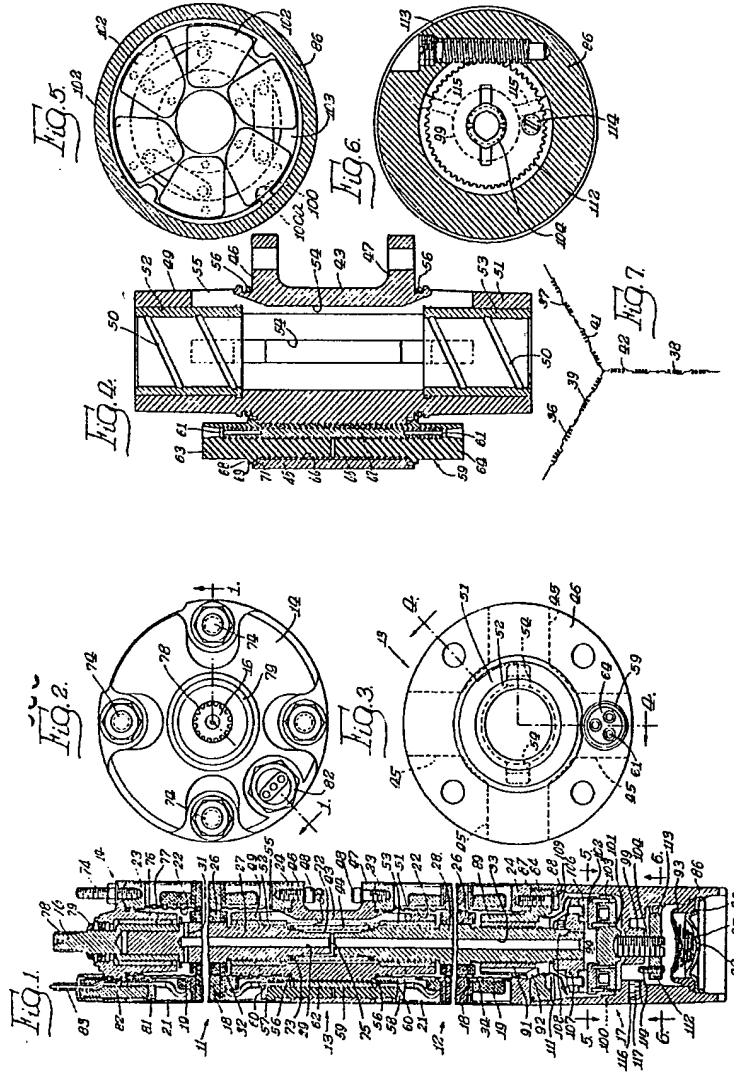
65 15. An electric motor interconnecting unit constructed and adapted to operate substantially as herein described with particular reference to the embodiment illustrated in the accompanying drawings.

70 16. A submersible electric motor assembly constructed and adapted to operate substantially as herein described with particular reference to the embodiments illustrated in the accompanying drawings.

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